PARTICULATE EMISSIONS OF A COTTON GIN IN THE TEXAS STRIPPER AREA

Production Research Report No. 149

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

CONTENTS

Washington, D.C. Issued May 1973

For sale by the Superintendent of Documents,
U.S. Government Printing Office, Washington, D.C. 20402

Price 30 cents domestic postpaid or 20 cents GPO Bookstore

Stock Number 0100-02743
Washington, D.C.

PARTICULATE EMISSIONS OF A COTTON GIN IN THE TEXAS STRIPPER AREA

By C. B. Parnell, Jr., and Roy V. Baker, *agricultural engineers, South Plains, Ginning Research Laboratory, Southern Region, Agricultural Research Service, United States Department of Agriculture, Lubbock, Tex.*

INTRODUCTION

Particulate emission standards are being adopted by a number of air pollution control agencies serving the Cotton Belt States. These standards will affect all sources of particulates, including cotton gins. The development of emission standards for cotton gins is a relatively new undertaking. Only limited information is available to guide the control agencies. Consequently, these agencies have to rely on past experiences with standards developed for other industrial processes. Cuffe [1] described two different approaches used in the past by several control agencies. These approaches were designed to limit emissions to some specified weight of particulates per unit volume of exhaust gas and to establish emission levels based upon process weight. The process weight method has been selected by the Texas Air Control Board [2] as the primary standard for cotton gins and other agricultural processers in that State.

Emission standards based upon process weight specify allowable particulate emissions in pounds per hour. The allowable emissions depend upon the pounds of raw material processed per hour. This is an exponential relationship wherein higher emissions are allowed for larger process weights but at a lower order of magnitude. A workable standard based upon this method requires detailed information on the particulate emissions from well-controlled cotton gins.

Information is available on particulate emissions from cotton gins processing machine-picked cotton. In 1969–70, McCaskill and Wesley [3] measured the emissions from a Mississippi gin. Their results showed particulate emission rates ranging from an average of 13.5 to a high of 30 pounds per hour when ginning machine-picked cotton. Particulate emissions from gins processing machine-stripped cotton were not known, but it was assumed they would be higher because stripped cotton contains more foreign matter.

PURPOSE AND SCOPE

The primary objective of this investigation was to determine the total particulate emission rate from a gin processing machine-stripped cotton. The investigation was conducted during 1970–71 at the USDA South Plains Cotton Ginning Research Laboratory, Lubbock, Tex. The Laboratory's ginning system was chosen because it was equipped with a complete and modern air pollution abatement system. Hence, results of this investigation could be considered a lower limit that other gins could achieve under ideal conditions.

In preparing for this study, other pertinent problems arose. Some stripper harvesters are equipped with field extractors which decrease the quantity of foreign matter in the seed cotton brought to the gin. We hypothesized that the use of field extractors could decrease the total particulate emitted by the gin. As a separate study, field extracted and nonfield extracted cotton were ginned and the total dust emission levels were compared. The objective of this part of the investigation was to determine if field extraction of seed cotton significantly reduced particulate emissions by a cotton gin.

Another question that arose concerned the

[1] Cuffe, S. T. control and disposal of cotton-ginning wastes. U.S. Pub. Health Serv. Pub. 999–AP–31, pp. 93–91. 1967.

[2] Amendment to Regulation I of 1972, Texas Air Control Board, as authorized under Section 3.10(e) of the 1969 Texas Clean Air Act.

[3] McCaskill, O. L., and Wesley, R. A. tests conducted on exhausts of gins handling machine picked cotton. The Cotton Gin and Oil Mill Press, pp. 7–9. 1970.

method of calculating the total particulate matter emitted by the gin in units of pounds per hour. The emitted air at the Laboratory was sampled at ginning rates lower than what is customarily used at commercial gins. To accurately project the total emission level for a 10 bale-per-hour ginning rate (a typical rate for commercial gins), it was necessary to examine the relationship between emission rates and feed rates for a seed cotton-cleaning system. A third test was conducted in which a uniform source of seed cotton was fed through the seed cotton cleaning system at three rates, and the particulate emission levels of the four exhausts associated with this system were compared.

The purpose of this investigation was threefold. (1) The primary objective was to obtain estimates of the total particulate emission rates for the South Plains Cotton Ginning Research Laboratory. The air pollution abatement system for this laboratory is complete and is as good or better than most cotton gins on the Plains. Hence, results of this investigation were considered to be a lower limit of what could be expected at other cotton gins processing stripper-harvested cotton. (2) A second objective was to obtain estimates of emission rates for field extracted and nonfield extracted cottons and to determine if the field extracted cottons did significantly decrease the total particulate emitted from a cotton gin. (3) A third objective was to evaluate the effects of different feed rates on the particulate emitted by the seed cotton cleaning system.

PROCEDURE

Air Sampling Network

During the initial planning for the air sampling network, the following requirements were established to help insure accurate results: All exhausts would be sampled only when the air emitted by the exhausts contained its maximum dust loading (It was assumed that whenever exhaust air had been used to actively convey material within the ginning system, this air contained its maximum dust loading.); all air sampling would be performed isokinetically;[4] all air samplers would be located within the gin building to facilitate the changing of exposed glass fiber filters; and a large number of air samples would be taken.

The Laboratory's ginning system for machine-stripped cotton was used for this test and is shown schematically in figure 1. The 10 exhausts were divided into the following categories for sampling: (1) unloading system, (2) seed cotton cleaning system, (3) overflow system, and (4) lint cotton handling system.

A control system was required to satisfy the planning requirements. Figure 2 shows a schematic of the control circuit. The primary control elements were two single-pole, single-throw (SPST) relays and two four-pole, single-throw (FPST) relays. There were four control elements (one for each of the four subsystems) that actuated the relays turning the air samplers on and off automatically.

The microswitches (fig. 2) on the input-feed control and the overflow-feed control were used to actuate the four air samplers associated with the seed cotton cleaning system (fig. 1, stations 1, 2, 3, and 4) and the overflow system (fig. 1, station 5), respectively. These microswitches were used by the ginning system to actuate feed motors associated with the input hopper or the overflow hopper. When actuated, these feed motors fed cotton to the seed cotton cleaning system (input-feed control) or to the distributor (overflow-feed control). All air samplers associated with the seed cotton cleaning system were turned on and off automatically when the input-feed motor was actuated. The error associated with the timelag for material to pass from station 1 to station 4 was assumed negligible.

The solenoid on the gin breast (fig. 2) was used to actuate the four air samplers associated with the lint cotton handling system (fig. 1, stations 6, 7, 8, and 9). Whenever the solenoid was actuated, the gin breast "kicked in" causing lint-seed separation to take place. It was assumed that whenever lint-seed separation was taking place, lint was being conveyed to lint cleaners. All air samplers associated with the lint cotton-handling

[4] American Society for Testing Materials. ASTM standards. Amer. Soc. Testing Mater. D 1356–67a, pp. 345–351. 1968.

system were turned on and off automatically when the gin breast solenoid was actuated and deactuated, respectively. Any error associated with the timelag for material to pass from stations 6 to 8 was assumed negligible.

All air samplers were located inside the gin building. Figure 3 shows the position of air sampling points relative to the gin building. Eight air sampling stations were located in air sample room 1. Two were located in air sample room 2. Four of the eight air sampling stations in room 1 were grouped for one man's responsibility with the remaining four assigned to another individual. Three men were required to operate the air sampling network. Figure 4 shows a set of four air sampling stations (2, 4, 5, 10) which were

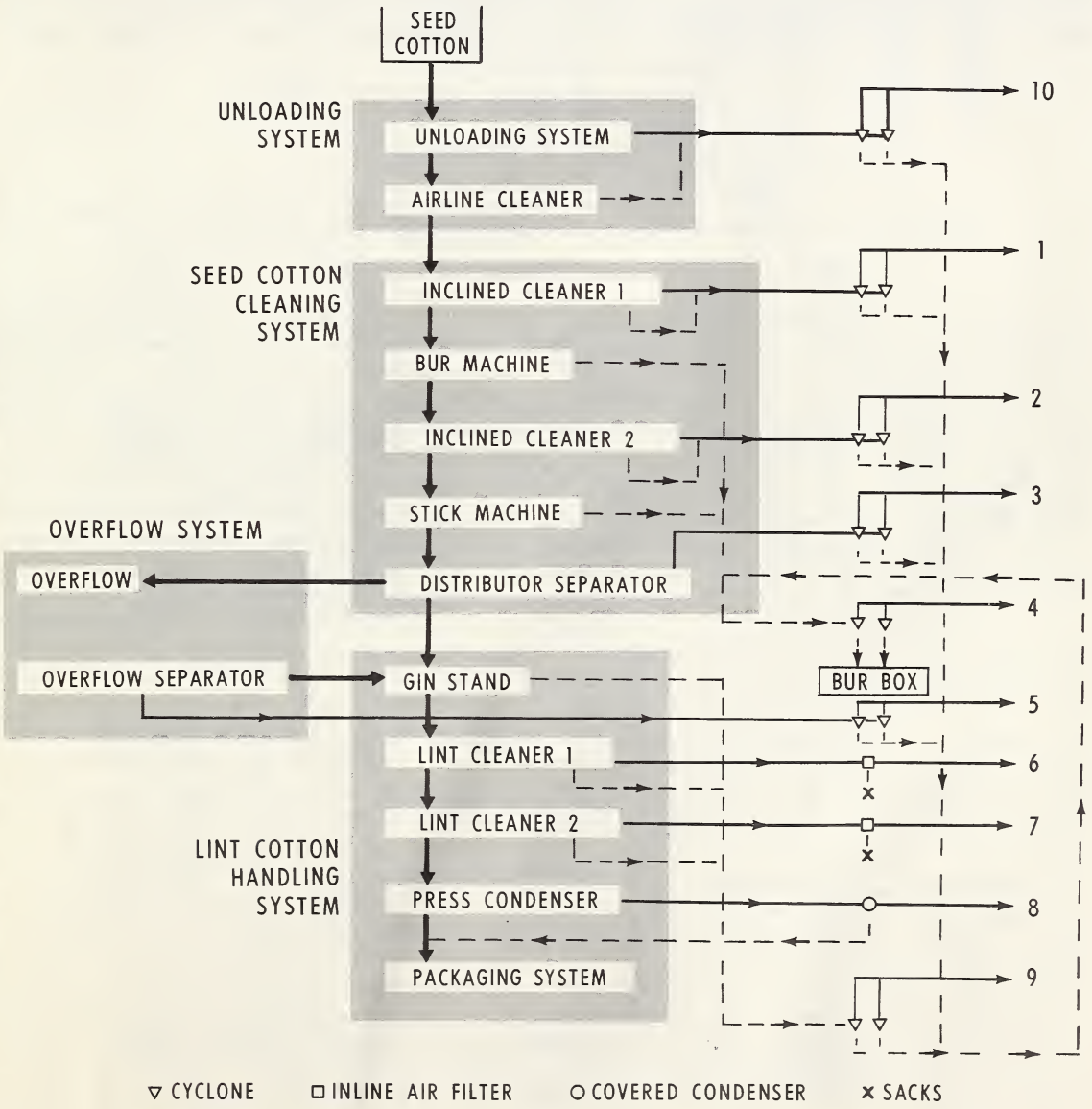


FIGURE 1.—Cotton ginning system showing the 4 subsystems and 10 exhausts that were sampled.

monitored by one of the required personnel. Note the air samplers, manometers, variable voltage transformers and clip boards holding data sheets.

The control system provided the means by which all exhausts could be sampled simultaneously, that is, for each lot of cotton processed by the ginning system, every exhaust was sampled as it was being processed by different subsystems of the ginning system. This procedure provided a much more accurate measure of the total particulate emission than the procedure where each exhaust was sampled separately since there was no means of controlling the level of foreign matter in the cotton brought to the gin. The control system limited sampling to those time periods when material was being conveyed by the air; hence, the concentrations of particulate were near a maximum for each exhaust.

The control of the air sampler on station 10 was accomplished by two switches in series. Both switches had to be in the "on" position for the air sampler to be sampling. One switch had to be turned on manually at the consol; the other was activated by a leaf-valve in the input hopper.

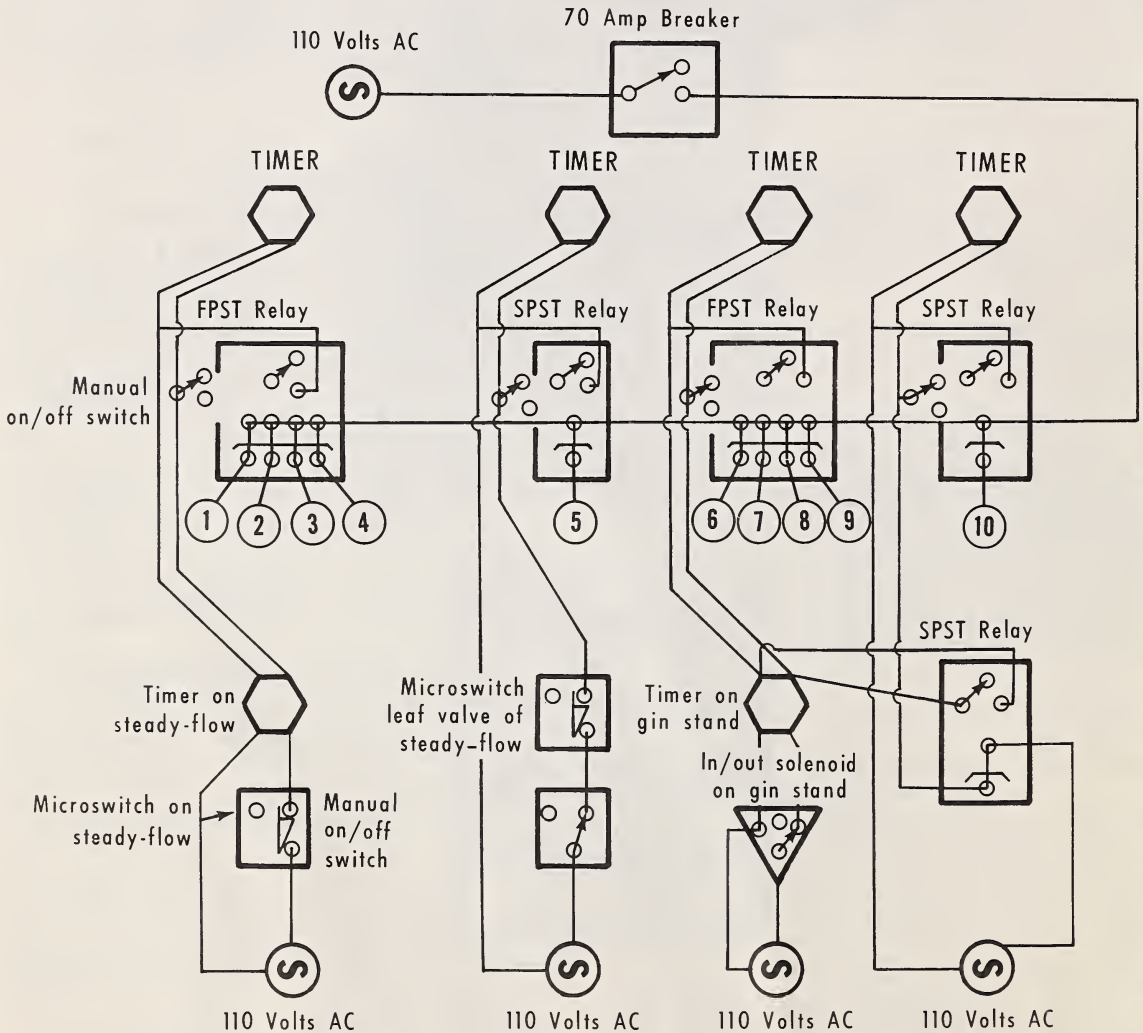


FIGURE 2.—Electrical control system for air sampling network.

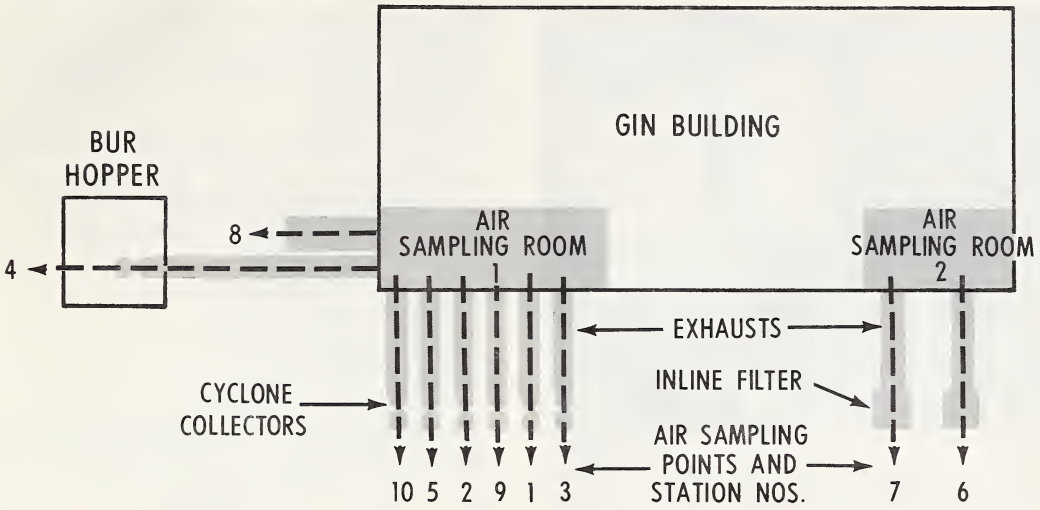


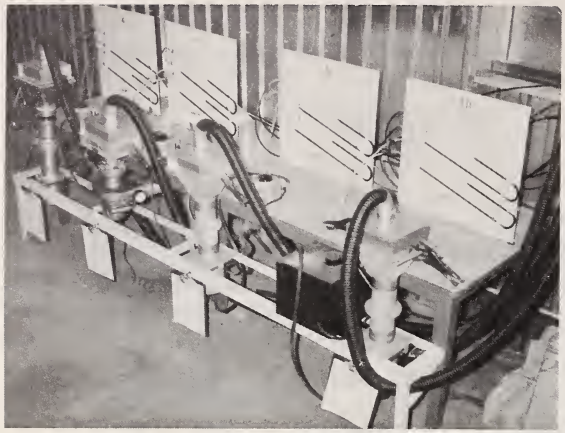
FIGURE 3.—Physical locations of air sampling points and air sampling rooms relative to gin building.

The leaf-valve switch automatically cut off the suction air when the hopper was filled. This allowed the cotton to be fed to the seed cotton cleaning system at a slower rate than it was fed to the input hopper. The air sampler on station 10 was turned off automatically when the leaf-valve cut off the suction air and when the switch on the consol was turned off. The console switch was turned off by the ginner when all the seed cotton that was to be ginned in that particular test lot had been fed in. There was some deviation from the requirement that air be sampled only when it had been used to actively convey material in the ginning system in that there was no guarantee that the suction pipe operator was feeding cotton to the ginning system when air was turned on the suction pipe. This meant that the air sampler on station 10 may have sampled some air that was not used to actively convey material in the ginning system, which may have resulted in an estimate of particulate matter concentration that was less than the true value. However, the procedure for calculating the emission per bale values compensated for this error, and the resultant deviations from true emission per bale values were considered negligible.

Before the air sampling network could be operated, nozzles had to be designed and built for the air sampling probes. These nozzles were designed on the basis that each air sampler was capable of sampling 40 actual cubic feet of air per minute for the periods in which material was being actively conveyed within the ginning system. The lines conveying the polluted air from the sampled point to the filter pad were set at 2 inches inside diameter (I.D.). Pitot tube (20-point) traverses were obtained for each exhaust for velocity distributions and an estimate of the average emission velocities. Appendix table 1 summarizes the results of this analysis and includes the designed inlet probe diameters for each exhaust.

Another prerequisite was a method for insuring isokinetic sampling. Inclined glass tube manometers were designed and built to allow the person monitoring each station to observe the emission air velocity and the sampled air velocity. Variable voltage transformers (variacs) were used to control the motor speeds of the universal air sampler motors which in turn controlled the sampled air velocity. Pitot tubes which were placed in the emission airstreams near the sampling points of all stations, except 6 and 7, were used to sense emission velocity. Orifice meters were used to sense the sampled air velocity. Each orifice meter was calibrated using a Meriam Laminar Flow Meter and placed in the sampled air line immediately following the glass fiber filter.

Specially constructed scales were placed in the background of the manometer. By superimposing



PN–3025

FIGURE 4.—Air sampling stations 2, 4, 5, and 10 including variable voltage transformers, high-volume air samplers, and specially constructed manometers.

the manometer fluid level on the scale, velocity and pressure readings were obtained. Each manometer had two scales in the background, one for velocity and one for pressure. The velocity scales were constructed to allow the monitoring personnel to read the air velocity of the emission air and sampled air, directly and simultaneously. This was accomplished by placing the two inclined manometers on a vertical board, one above the other, with each having its own scales. The air velocity scales for the orifice meters incorporated the inlet cone diameters (appendix table 1), calibrated orifice constants (appendix table 2), and assumed an air density of 0.065 pounds per cubic foot. The air velocity scales for the pitot tubes incorporated the same air density.

It was decided in the planning stage that the velocity read directly would not be accurate enough for the required analysis since the air density changed considerably. Hence, an algorithm was developed of air density as a function of relative humidity, temperature, and barometric pressure. The calculated air densities (equation 25, Appendix I) were used to determine the actual air velocities and flow rates. The velocity pressures of pitot tubes and the differential pressures across orifice meters in units of inches of water were recorded while the air sampling was taking place. Approximately 1,100 glass fiber filters were preweighed in preparation for sampling.

The required data for each air sample consisted of the following:

1. Fiber filter weights (before and after exposure)
2. Differential pressure across orifice meter
3. Velocity pressure on pitot tube
4. Test-lot number
5. Air sampling time
6. Lint weight of lot
7. Relative humidity
8. Temperature
9. Barometric pressure

The particulate concentration values were calculated, using equation 1 as follows:

$$C_1 = W/Q \qquad (1)$$

where C_1 is the dust concentration in units of grams per cubic meter; W is the weight of particulate caught on high volume filter in grams; and Q is the volume of air sampled in cubic meters determined by multiplying the volume rate of flow (calculated from differential pressure across orifice meter, air density, and orifice constant) times the sampling time.

The concentration values were used to estimate the emission rate in units of pounds dust per bale, using equation 2 as follows:

$$C_2 = \left(C_1 \times Q_e \times \frac{1}{454}\right) \Big/ \left(LW \times \frac{1}{478}\right) \qquad (2)$$

where C_2 is the dust emission rate in pounds per bale; C_1 is the dust concentration in units of grams per cubic meter; Q_e is the emission air volume in units of cubic meters (calculated from pitot tube velocity pressure, air density, emission pipe cross-sectional area, and emission time); and LW is the lint weight in pounds.

Data were obtained while ginning four test cottons. Test cotton 1 was a Tamcott 788 variety produced near Ralls, Tex., and harvested the first week of November. Test cottons 2, 3, and 4 were harvested in mid- to late November and were produced near Shallowater, Tex. Test cotton 2 was a Stripper 31 variety and test cotton 3 was a Paymaster 111 variety. Test cotton 4 consisted of six varieties of cotton harvested by a mechani-

cal stripper that was not operating properly. A mechanical defect allowed the stripper mechanism to descend so low that large amounts of loose soil were picked up and mixed with the cotton. Although this condition was not common that season, this dirty cotton was included in our test to obtain a measure of the maximum dust emission expected from a gin processing stripper-harvested cotton.

A computer program was written to transform the raw data into emission concentrations in grams per cubic meter and emission rates in pounds per bale. Appendix II contains a flow chart of computer program. Data analysis was performed by an IBM 360/40 computer located at the ARS Data Systems Application Division, Beltsville, Md. Included in the analysis was an algorithm that calculated the average plus or minus three standard deviations.[5] All data not within this range were removed before calculating the final average and standard deviation. It was assumed that data not within this range had an external error associated with it.

Field Extracted Versus Nonfield Extracted Test

The test cotton was Lockett 4789 variety, harvested with a finger-type stripper equipped with a field extractor. The air emitted by the Laboratory while processing cotton harvested by the same harvester and from the same field was sampled by the air sampling network. One-half of the cotton was processed through the extractor and one-half bypassed it. The cotton was harvested on October 29, November 19, and December 9. The cotton from each harvest date was used for a complete replication.

Feed Rate Versus Emission Rate Test

To convert the total emission rate in pounds per bale to a corresponding rate in pounds per hour, it was necessary to consider the ginning rate. One simple method of accomplishing this conversion is to multiply the pounds per bale emission values by the desired ginning rate. This method is based on the assumption that the emission rate per bale remains constant at different ginning rates. This assumption is logical for those exhausts following the gin stand since this equipment operates within a relatively narrow range of processing rates; however, seed cotton cleaning machinery is operated over a much broader range. This situation makes the above assumption questionable. Because of this, a test was performed to determine if different processing rates through the seed cotton cleaning system affected the particulate emission rates per bale.

Control of feed rates through the seed cotton cleaning system was accomplished by changing the settings on the variable feed motor that drove the feed mechanism on the feed control.

RESULTS

Air Sampling Network

The average concentrations with standard deviations for each exhaust are given in appendix table 7. Appendix table 4 contains a more in-depth analysis of what was being emitted by the ginning system. The totals and subtotals were obtained by first calculating the emission rate in pounds per bale by equation 2. The percentages of the total were presented along with the individual pounds-per-bale values to emphasize the exhausts that were heavy emitters. Comparing subtotals, it can be seen that the lint cotton handling system was the heaviest emitter. This is a significant result. Normally, one would think that the unloading system or the seed cotton cleaning system would be the heaviest emitters since the cotton contains more foreign matter while being conveyed by these subsystems.

One factor that caused the lint cotton handling system to be the heaviest emitter was the volume

[5] Mosteller, Frederick, Rourke, R. E. K., and Thomas, G. B. Jr. probability and statistics. 395 pp. Addison-Wesley Publishing Co. Reading, Mass. 1961.

of air handled by this system. The emission volume rate of flow was significantly higher for stations 6, 7, and 8 (see appendix table 1). The time required to convey material for this subsystem corresponded to the time required to gin the cotton. This is perhaps the slowest operation in the ginning system. The procedure used to calculate the total emission volume incorporated the time material was being conveyed. This resulted in the lint cotton handling system having a longer emission time and a large volume rate of flow, hence, a much larger emission volume than other exhausts. Since the particulate concentrations of exhaust 6 (appendix table 3) were as large or larger than all others, it is logical that the total emission levels (pounds per bale) were high. In general, table 4 shows that if one could eliminate exhaust 6, a reduction of as much as 50 percent of the total dust emitted could be realized.

Appendix table 4 also points out the increase in total particulate emitted with harvesting time. The total particulate emitted doubled with a difference of 15 to 20 days between harvesting dates of test cotton 1 and test cottons 2 and 3. The difference may also be a consequence of the stripper and its operator. As explained previously, the stripper on test cotton 4 was not adjusted properly, and large amounts of soil were mixed in with the harvested cotton. The results indicate the total particulate emitted by the gin increased considerably when the harvester was not operating properly. A higher-than-normal percentage of the total particulate was emitted by the unloading system.

Field Extracted Versus Nonfield Extracted Cotton Test

Does field extracted cotton significantly reduce the particulate emissions of a cotton gin? It seems logical that if one were to decrease the trash content of the seed cotton brought to the gin, then the total particulate emitted should also decrease. The test was arranged so that the cotton would be harvested on three different dates. Emission rates were highly dependent upon time of harvest, which disallowed the combination of the data for the three harvest dates. Figure 5 contains the results of these samples.

The data are the sum of emissions from each exhaust. It is difficult to formulate definite conclusions on the limited data available; however, the field extraction process did decrease the total emission rate for all three harvesting dates. The decrease ranged from 1 to 36 percent. The average decrease in emission was 23 percent for the three harvest dates.

Feed Rate Versus Emission Rate Test

It was critical in this test that the seed cotton fed to the seed cotton cleaning system be uniform. Appendix table 5 contains the foreign matter contents of the test cottons at the wagon and at the feeder. Three wagon fractionations and one feeder fractionation were obtained for each lot. There were no significant differences in percentage of burs, sticks, and fine trash between lots. This result supports the assumption of uniform seed cotton fed to seed cotton cleaning system.

There was no precise means of controlling feed rate as can be observed in appendix table 6; however, feed rates were controlled within limits. Three settings, corresponding to high, medium, and low, were randomly assigned for each replication. One-bale lots were used, and data were obtained for six replications.

The hypothesis of this test was that the particulate emission rate from the seed cotton cleaning system was directly proportional to the feed rate through the system. In other words, doubling the feed rate also doubles the dust emission rate. It is necessary that we have some detailed analysis of this problem before discussing results. The method used to control the air samplers limited the sampling of the emission air to whenever material was being transported by the system. This meant that faster feed rates resulted in shorter sample times and shorter emission times (assuming emission time to be identical to the time material is being transported by the system). The emission time (t) determined the air volume (Q) emitted, which contained a certain particulate concentration.

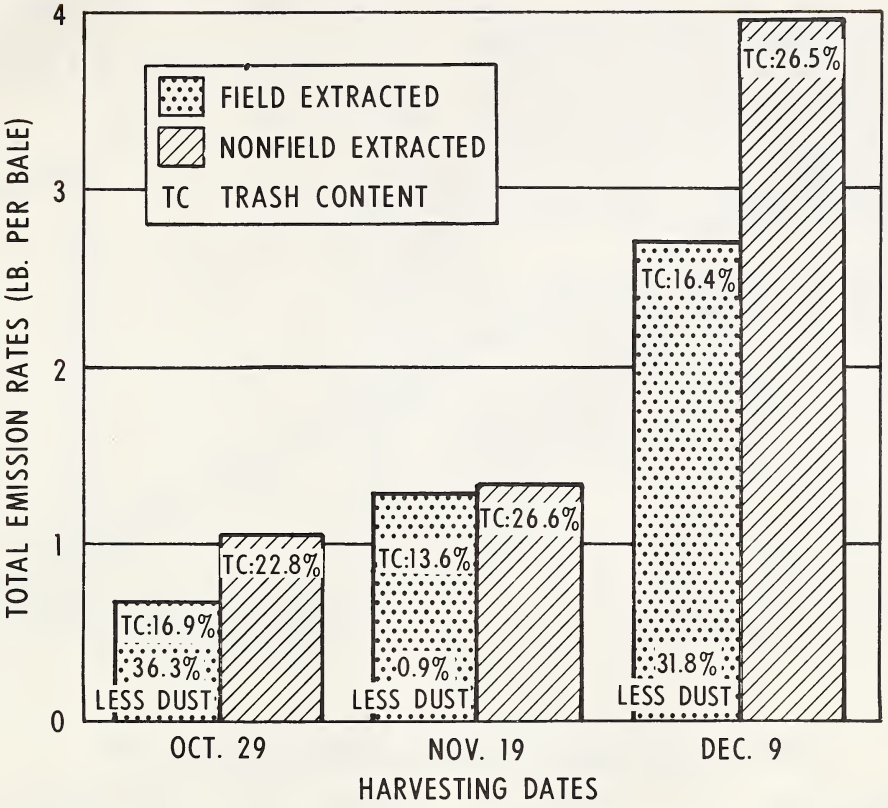


FIGURE 5.—Summary of results from the extracted versus nonextracted test.

$$Q = V t \quad (3)$$

where, Q is the emission air volume, V is the emission flow rate in actual cubic feet per minute, and t is the emission time.

We assumed that the air volume did not change with the three feed rates used in this test.[6] We were trying to show that the emission rate (pounds per hour) of the seed cotton cleaning system cannot be accurately determined by equation 4 for feed rates other than the one used to measure the dust concentration.

$$ER = C \times FR \quad (4)$$

where, ER is the emission rate in pounds per hour, C is the dust concentration in pounds per bale, and FR is the feed rate through seed cotton cleaning system in bales per hour.

Note in equation 4 that C must be constant for emission rate to be directly proportional to feed rate. Hence, the criterion for determining if we could double the emission rate when we doubled the feed rate was to measure C at several different feed rates and check to see if it varied significantly. Statistical analysis of results is shown in appendix table 7.

It was concluded from the analysis of results that the emission concentration (C) in units of pounds dust per bale was not a constant value for different feed rates through the system. The

[6] A small change in air volume was detectable. The higher feed rates resulted in a slightly lower volume. This was attributed to the increase in energy required to convey more material; however, the decrease was small and considered to be negligible.

slow feed rate resulted in a significantly greater emission rate. Figure 6 is a plot of the emission rate versus feed rate relationship. The procedure required to estimate the total dust emission rate in pounds per hour from a gin processing cotton at a rate of 10 bales per hour would be as follows:

1. Establish the emission concentrations (C) in pounds per bale for a specific processing rate.
2. Determine the emission rate in pounds per hour for all exhausts except those from the seed cotton cleaning system by multiplying processing rate times C.
3. Determine emission rate in pounds per hour for the seed cotton cleaning system by multiplying the processing rate times the modified C. The modified emission concentration is increased or decreased depending upon whether the processing rate is less than or more than the rate at which C was determined.
4. Sum emission rates from all exhausts.

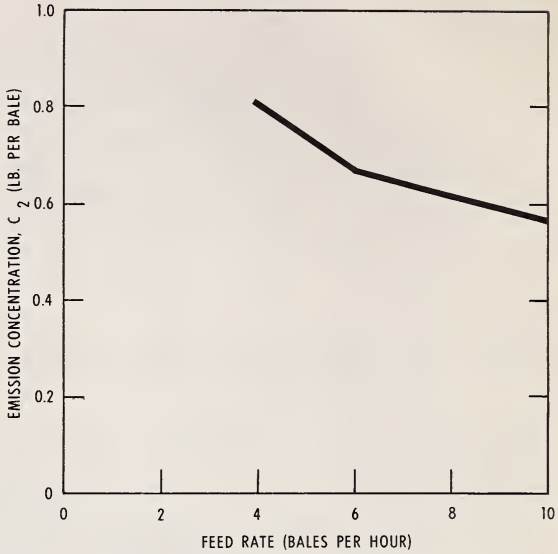


FIGURE 6.—Emission concentration in pounds per bale for seed cotton cleaning system versus feed rate in bales per hour through system.

RELATING RESULTS TO PROCESS WEIGHT

Cotton gins in Texas will be subject to the standards outlined in Regulation I of the Texas Air Control Board Authorized and Section 310 (e) of the 1969 Texas Clean Air Act. The process weight table included in this regulation lists the limits of dust emission in pounds per hour corresponding to the pounds per hour of raw material processed. These limits are as follows:

$$EL = 3.12\ p^{0.985} \quad (p < 20 \text{ tons per hr.}) \qquad (5)$$

$$EL = 25.4\ p^{0.287} \quad (p > 20 \text{ tons per hr.}) \qquad (6)$$

where, EL is the emission limit in pounds per hour and p is the processing weight in tons per hour.

Appendix table 8 contains the emission levels in pounds per hour for each exhaust projected to a 10-bale-per-hour ginning rate and the confidence limit ($\alpha = 0.05$) associated with each average. The total emission levels were obtained by summing the average emission level of each exhaust. A range of total emission levels and trash contents were obtained for each test cotton by summing the averages minus the confidence limits and the averages plus the confidence limits (appendix table 9). Also included in Appendix table 8 were average trash contents in percent and their associated confidence limits and estimates of the processed weight required to yield a bale of cotton having a lint weight of 478 pounds.

It was noted in the analysis of results that there seemed to be a high correlation between the total emission levels and the percent trash contents. A linear regression equation was formulated using the average total emissions and the average trash contents as follows:

$$y = 2.61x - 54.1 \qquad (7)$$

where, y is the emission level in pounds per hour and x is the percent trash contents.

Equation 7 yielded a zero order correlation coefficient of 0.989 and a standard error of the estimate (s_{xy}) equal to 1.64.

Figure 7 summarizes the results of the air sampling network. Using equation 5, the emission limits for the four processed weights shown in appendix table 9 were calculated to be 28.4, 29.9, 31.8, and 34.6 lbs. per hr., respectively. Equation

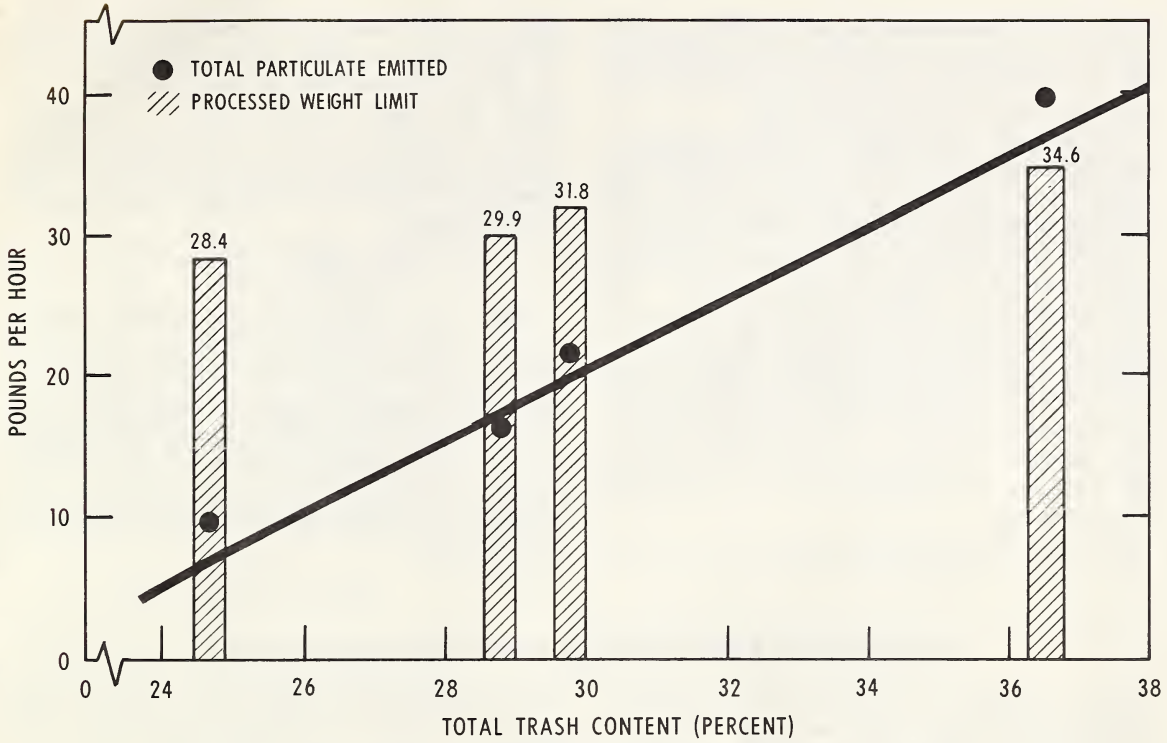


FIGURE 7.—Summary of results of air sampling network.

7 is plotted in figure 7 along with the actual data points. Note that with a complete air pollution abatement system, the total emission level did not exceed the emission limits except in the case of test cotton 4, which was an extremely dirty cotton.

SUMMARY AND CONCLUSIONS

A special air-sampling network was used to measure the particulate emissions from a cotton gin processing stripper-harvested cottons. The network was designed to obtain representative air samples from all 10 of the gin's exhaust points. Investigations included measurements of particulate emissions from the Laboratory's ginning system while processing four different test cottons—field extracted and nonfield extracted cottons—and while processing cotton at three different cleaning rates.

Results of the air-sampling network for the four different test cottons with approximately 18 air samples per exhaust per test cotton were presented in a table of average emission levels for each exhaust in units of pounds per bale. The sum of the average particulate emissions from each exhaust ranged from 0.986 pounds per bale for the test cotton containing the least amount of foreign matter to 4.028 pounds per bale for the test cotton containing the largest amount of foreign matter. Considerable variations of particulate emissions from each exhaust were encountered when calculating the averages. For this reason, high and low particulate emission values of each exhaust, in pounds per bale, were calculated by adding and subtracting the confidence limit ($\alpha = 0.05$). Estimates of the high and low total emission values, in pounds per bale, were obtained for each test cotton by summing the individual highs and lows of each exhaust.

A test was conducted to compare the emissions

of the laboratory's ginning system while processing field extracted and nonfield extracted cotton. The field extracted cottons decreased the total emissions approximately 23 percent.

Another test was conducted to determine if the feed rate to the seed cotton cleaning systems significantly affected the emission rate in pounds per bale. It was found that the particulate emissions per bale from the seed cotton cleaning system decreased as the feed rate increased. This information was used to determine the projected emissions in pounds per hour for a gin processing cotton at a rate of 10 bales per hour. The average particulate emissions ranged from a low of 9.8 pounds per hour for the test cotton having the least foreign matter to a high of 39.6 pounds per hour for the test cotton having the most foreign matter.

In an examination of the results, it was found that a high correlation existed between the foreign matter content of the seed cotton found on the trailer and the particulate emission rate from the cotton ginning system. A regression analysis yielded an equation depiciting the laboratory's emission rate (y) in units of pounds per hour as a function of seed cotton trash content (x) in percent:

$$y = 2.61x - 54.1 \quad (8)$$

One of the most significant results obtained in this investigation was that the particulate emission from the first lint-cleaner exhaust accounted for over half of the total particulate emitted by the entire ginning system. This identifies an area where potential improvements could be made to significantly reduce the particulate emissions from a cotton gin processing stripper-harvested cotton.

RECOMENDATIONS FOR FUTURE RESEARCH

This investigation was concerned with measuring quantitative particulate emission values for a cotton gin equipped with a complete abatement system for processing stripper-harvested cotton. Many commercial gins do not have a complete abatement system. What would be the minimum abatement system required by a commercial gin to stay within established regulation limits?

In general, cyclones are used to abate particulates of centrifugal fan exhausts and inline filters are used for axial-flow fan exhausts. The decision as to whether to use an inline filter or cyclone for a particular exhaust should consider the properties of the particulate as well as the fan type. A study of physical properties of the particulates by type of exhaust should be made. It may be found, for example, that an inline filter would work better on the mote line's exhaust because of a predominance of lint particles, even though a centrifugal fan is used to move the air. Along this same line, an inline filter applied to a centrifugal fan exhaust would not have to be as big as those on axial-flow fan exhausts since a centrifugal fan system can withstand considerable back pressure.

We have found in this study that the ginner does not have full control over the quantity of particulate that is emitted from his cotton gin. Seed cotton having a high level of foreign matter will most likely increase the particulate emissions from a gin even if the gin is equipped with a complete abatement system.

APPENDIX I—BAROMETRIC PRESSURE, RELATIVE HUMIDITY, AND TEMPERATURE COMPENSATIONS IN AMBIENT AIR DENSITY

The molecular weight of air is 28.996 and that of water vapor is 18.016. At standard conditions (32° F. and 29.92 in. Hg) a gas will occupy 359.03 cu. ft. per lb.-mole. The ideal gas law is given as follows:

$$PV = n\,R\,T \quad (9)$$

where, P is the absolute pressure, V is the volume occupied, n is the lb.-moles (English system), R is the ideal gas law constant, and T is the absolute temperature.

Working with weights (W) of gases in pounds, the ideal gas given by equation 9 may be modified as follows:

$$PV = \frac{W}{MW} RT. \tag{10}$$

$$PV = WR'T \tag{11}$$

where, $R' = R/MW$.

The ideal gas constant may be calculated as follows:

$$R = \frac{PV}{T} = \frac{(29.92 \text{ in.Hg})\ (359.03)\ \text{ft.}^3}{(32 + 459.7)°\text{R}}$$

$$= 21.847 \frac{(\text{in.Hg})(\text{ft.}^3)}{\text{lb.-mole}°\text{R}} \tag{12}$$

The value of R for air and water vapor is given by equations 13 and 14 as follows:

$$R'_a = \frac{R}{MW} = \frac{21.847}{28.966} = 0.7542 \tag{13}$$

$$R'_w = \frac{21.847}{18.016} = 1.2126 \tag{14}$$

The density of a gas is given by equation 15 as derived from equation 11 as follows:

$$\gamma = \frac{W}{V} = \frac{P}{R'T} \tag{15}$$

Since γ is an extensive variable, the density of an air-water vapor mixture may be determined by adding the calculated densities of dry air and water vapor, which are given by equations 16 and 17 as follows:

$$\gamma_a = \frac{P_a}{R'_a T} \tag{16}$$

$$\gamma_w = \frac{P_w}{R'_w T} \tag{17}$$

Barometric pressure is a measure of the total air pressure; that is, water vapor pressure plus dry air pressure. The dry air pressure is determined by subtracting the water vapor pressure (P_w) from the barometric pressure (b). The water vapor pressure is calculated as follows:

$$P_w = hS \tag{18}$$

where, P_w is the water vapor pressure, h is the relative humidity, and S is the saturated water vapor pressure.

Equation 19 is used to calculate dry air pressure as follows:

$$P_a = b - hS \tag{19}$$

Substituting equations 18 and 19 into equations 16 and 17 along with calculated values of R_a and R_w we get the following:

$$\gamma_a = \frac{b - hS}{0.7542T} \tag{20}$$

$$\gamma_w = \frac{hS}{1.2126(T)} \tag{21}$$

The absolute temperature (T) is determined from equation 22 as follows:

$$T = (459.7 + t) \tag{22}$$

where, T is the absolute temperature in degrees Rankine and t is the temperature in degrees Fahrenheit.

Substituting equation 22 into equations 20 and 21 and simplifying we get the following:

$$\gamma_a = \frac{b - hS}{346.7 + 0.7542t} \tag{23}$$

$$\gamma_w = \frac{hS}{557.4 + 1.2126t} \tag{24}$$

Equation 25 shows the calculations required to determine air density.

$$\gamma_m = \gamma_a + \gamma_w = \frac{b - hS}{346.7 + 0.7542t} + \frac{hS}{557.4 + 1.2126t} \tag{25}$$

APPENDIX II—TABLES

TABLE 1.—*Summary of air sampling network design data*

Source	Source description	Approximate length of sample pipe	Cone inlet diameter [1]	Sampled air velocity [2]	Approximate emission air velocity	Approximate flow rate
		Feet	*Inches*	*Inches*	*Feet per minute*	*Cubic feet per minute*
1	Cleaner 1	25	1.14	1,826	5,620	7,843
2	Cleaner 2	25	1.16	1,830	5,440	7,592
3	Separator 5	25	1.22	1,827	4,910	6,852
4	Trash fan	80	1.34	1,832	4,300	6,001
5	Overflow	25	1.22	1,827	4,910	6,852
6	Lint cleaner 1 condenser	25	3.10	2,468	786	8,310
7	Lint cleaner 2 condenser	25	3.10	1,403	584	8,252
8	Press condenser	35	2.10	1,838	1,667	13,123
9	Unit motes	25	1.55	1,825	3,040	4,242
10	Unloading separator	25	1.04	1,838	6,800	9,490

[1] To have isokinetic sampling, the diameter of the entrance of the sampling tube was specified by a projected sampling volume of 40 cu. ft. per min.

[2] Air containing particulate is conveyed from sampling point to air sampler by 2-inch I.D. pipe at approximately 40 cu. ft. per min.

TABLE 2.—*Orifice constants and emission pipe cross-sectional area*

Station No.	Orifice constant	Emission pipe cross-sectional area
		Square feet
1	8.6301	1.3956
2	8.4822	1.3956
3	8.5077	1.3956
4	9.9813	1.3956
5	7.4419	1.3956
6	8.4465	10.5729
7	8.2247	14.1300
8	8.2859	7.8718
9	8.2731	1.3956
10	8.1227	1.3956

TABLE 3.—*Average concentrations and standard deviations of particulate emitted by the 10 separate exhausts sampled while processing four sources of seed cotton*

Station No.	Test cottons							
	1		2		3		4	
	$\bar{X}$[1]	σ[2]	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
	Mg./m.^{3}	*Mg./m.*^{3}	*Mg./m.*^{3}	*Mg./m.*^{3}	*Mg./m.*^{3}	*Mg./m.*^{3}	*Mg./m.*^{3}	*Mg./m.*^{3}
1	18.53	3.11	79.46	19.65	71.06	16.03	183.39	46.32
2	9.86	2.13	27.86	6.89	28.72	6.51	52.62	14.01
3	4.85	.64	10.49	3.15	10.55	2.45	21.45	4.72
4	18.73	6.40	137.10	40.23	91.87	18.56	147.25	38.18
5	18.76	10.37	5.62	2.78	9.98	3.72	14.01	5.21
6	36.62	7.99	71.24	12.52	107.11	38.14	111.05	28.06
7	7.07	1.48	11.47	1.77	11.17	3.01	[3]0	0
8	4.46	1.49	5.2	1.39	3.99	1.07	5.84	1.30
9	26.23	4.66	41.83	7.24	38.62	10.87	64.31	8.71
10	46.89	19.02	48.09	6.80	63.86	24.65	278.30	106.25

[1] $\bar{X}$ = average concentrations.
[2] σ = standard deviations.
[3] Lint cleaner 2 exhaust was not sampled in this test.

TABLE 4.—*Distribution and emission-per-bale values by exhaust for four test cottons*

Emission air exhaust system and station number	Test cottons							
	1		2		3		4	
	Percent	*Pounds per bale*	*Percent*	*Pounds per bale*	*Percent*	*Pounds per bale*	*Percent*	*Pounds per bale*
Seed cotton-cleaning system:								
1	5.67	0.056	12.29	0.190	8.40	0.180	10.84	0.437
2	3.04	.030	4.66	.072	3.64	.078	3.37	.136
3	1.41	.014	1.68	.026	1.32	.028	1.39	.056
4	4.25	.042	14.17	.219	7.74	.166	6.70	.270
Subtotal	14.37	.142	32.80	.507	21.10	.452	22.3	.899
Overflow system:								
5	6.69	.066	.77	.012	1.02	.022	0.69	.028
Lint-cotton handling system:								
6	35.69	.352	37.99	.587	49.47	1.060	28.2	1.136
7	5.07	.050	5.11	.079	4.20	.090	[1] 0	
8	7.50	.074	4.78	.074	3.17	.068	2.35	.095
9	8.51	.084	7.63	.118	6.20	.133	5.46	.220
Subtotal	56.77	.560	55.51	.858	63.04	1.351	36.01	1.451
Unloading system:								
10	22.1	.218	10.87	.168	14.79	.317	40.96	1.650
Total	100.0	.986	100.0	1.545	100.0	2.142	100.0	4.028

[1] Lint cleaner 2 exhaust was not sampled in this test.

TABLE 5.—*Results of statistical analysis of foreign matter content for feed rate versus emission rate test*

Item	Average percentage of trash[1]		
	Burs	Sticks	Fine trash
	Percent	*Percent*	*Percent*
Wagon	17.81	4.84	6.59
Feeder	.29	.26	2.85

[1] No significant difference in foreign matter content between sample lots at 5-percent level.

TABLE 6.—*Actual feed rates (bales per hour) measured for feed rate versus emission rate test*[1]

Feed rate	Replications					
	1	2	3	4	5	6
	Bales per hour					
High	2.18	3.81	3.80	3.68	3.67	3.60
Medium	5.38	5.78	5.68	5.28	5.50	5.53
Low	10.16	10.27	10.48	9.97	8.80	9.57

[1] Feed rates were calculated by dividing the time seed cotton was in the seed cotton cleaning system into the lint weight of the lot and using 478 pounds as the standard bale weight.

TABLE 7.—*Results of statistical analysis of particulate emission concentrations for the fast, medium, and slow feed rates through the seed cotton cleaning system*

Emission air exhaust stations	Feed rates			
	Fast	Medium	Slow	Significance[1]
	Pounds per bale	*Pounds per bale*	*Pounds per bale*	
1	0.191	0.296	0.287	*
2	.077	.083	.099	NS
3	.022	.023	.029	**
4	.284	.269	.399	**

[1] Results of analysis of variance: * = significant at 1-percent level; ** = significant at 5-percent level; NS = not significant.

TABLE 8.—*Emission levels with confidence limits ($\alpha = 0.05$) from each exhaust projected for a cotton gin processing stripper-harvested cotton at a rate of 10 bales per hour and average trash content with confidence limit ($\alpha = 0.05$)*

Emission air exhaust stations	Test cottons[1]			
	1	2	3	4
	Pounds per bale	*Pounds per bale*	*Pounds per bale*	*Pounds per bale*
1	0.488 ± 0.045	1.704 ± 0.233	1.671 ± 0.158	4.026 ± 0.319
2	.257 ± .025	.647 ± .082	.724 ± .084	1.259 ± .129
3	.129 ± .009	.235 ± .035	.265 ± .027	.515 ± .055
4	.363 ± .054	1.961 ± .296	1.545 ± .141	2.486 ± .312
5	.784 ± .346	1.213 ± .035	.228 ± .035	.280 ± .067
6	3.516 ± .459	5.875 ± .537	10.605 ± 1.837	11.362 ± 1.505
7	.507 ± .044	.793 ± .078	.904 ± .180	
8	.737 ± .122	.742 ± .096	.688 ± .101	.954 ± .081
9	.845 ± .071	1.179 ± .102	1.335 ± .204	2.207 ± .168
10	2.175 ± .500	1.677 ± .999	3.172 ± .719	16.507 ± 2.60
Total	9.800	16.025	21.136	39.596

[1] Average foreign matter content for test cottons 1, 2, 3 and 4 were 24.74, 28.80, 29.80, 36.49 percent, respectively. Average seed cotton processed weights projected to a 10 bale-per-hour ginning rate for test cottons 1, 2, 3, and 4 were 18,800, 19,870, 21,200, and 23,200 pounds, respectively.

TABLE 9.—*Range of total emissions for each test cotton in pounds of dust per hour and percent trash content*

Item	Test cottons							
	1		2		3		4	
	Low	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
Emission, pounds per hour	8.11	11.48	13.53	18.52	17.65	24.62	34.36	44.83
Trash content, percent	23.34	26.11	27.82	29.78	28.41	31.20	34.73	38.25

☆ U.S. GOVERNMENT PRINTING OFFICE: 1973 O—491–501